EEE 391

Basics of Signals and Systems

MATLAB Mini Project 1

Due: 23 February 2022, Wednesday by 23:00 on Moodle

Write your own MATLAB code to determine and plot the real and imaginary parts of complex exponential signals of the form

$$v_k(t) = Ae^{j(2\pi k f_o t + \phi)}$$

as a function of time, where k is an integer. Use the last two digits of your ID number as the A value; use the three digits before the last two digits as the f_o value. Use the uniformly distributed random number generator in MATLAB to generate the phase ϕ of the signal randomly in the interval $\phi : [-\pi, \pi]$. Select a suitable sampling interval T_s from the set $[\ldots, 10^{-5}, 10^{-4}, 10^{-3}, 10^{-2}, 10^{-1}, 1]$ to increment the time (time units in seconds) and uniformly sample the signal.

a) Using Euler's formula, determine the real and imaginary parts of a complex exponential signal whose parameters are generated as described above. Use a k value of 2. Specify the parameter values A, f_o, ϕ, T_s that you have used. Plot the real and imaginary parts over two fundamental periods.

b) Try at least two values of the sampling interval T_s for a given complex exponential signal at a certain fundamental frequency, amplitude, and phase [as in part a)]. For each case, write the corresponding (uniformly-sampled) discrete-time complex exponential and identify its digital frequency. Discuss the effect of changing T_s on the resulting sequence and on the digital frequency.

Your program should produce and print the radian frequency, the digital frequency, and the period of the signal as output. It should also calculate the time shift Δt corresponding to the phase shift ϕ.

c) Add up the elements of the real part that you have generated in part a) over one fundamental period (T_o). What do you get? Repeat for the imaginary part. Write a single discrete summation that corresponds to what you have done in this part and jointly covers the results of both the real and the imaginary parts.

d) Find the sum of the real parts of two complex exponentials with amplitude, fundamental frequency, and phase as in part a), corresponding to two *different* harmonics of the fundamental. For the first complex exponential, use $k = 5$, for the second, use $k = 7$. Use the same sampling interval for both complex exponentials. Specify and print the parameter values that you have used. Plot your result over one fundamental period (T_o). Calculate the sum of the sum elements for one, three, and five fundamental periods. What are your observations? Does the sum converge to any value as the summation interval is increased?

e) Find the inner product of two complex exponentials with amplitude, fundamental frequency, and phase as in part a), corresponding to two *different* harmonics of the fundamental. Use the same k values and the same sampling interval as in part d). Plot your result over one fundamental period (T_o). Calculate the sum of the product elements for one, three, and five fundamental periods. What are your observations? Does the sum converge to any value? What would happen if you had not considered an integer number of fundamental periods? Based on your results, what can be concluded about complex exponentials at frequencies that are integer multiples of a fundamental (for two *different* integer orders)? Can you relate this to the orthogonality principle, the inner product of two functions (signals), and the choice of basis functions for Fourier series representation of periodic signals? What is the main reason behind choosing such complex exponentials for the Fourier series representation of periodic signals?

f) What happens if you make the two frequencies in part e) the same, say using a k value of 5 for both, corresponding to the fifth harmonic? Use the same sampling interval as in parts d) and e). Plot your result over one fundamental period (T_o). Calculate the sum of the product elements for one, three, and five fundamental periods again. What are your observations? Does the sum converge to any value as the summation interval is increased? What does this result correspond to? Can you relate this to the orthogonality principle and the inner product of two functions?

Submit the results of your own work in the form of a well-documented report on Moodle. Borrowing full or partial code from your peers or elsewhere is not allowed and will be punished. Please include all evidence (plots, screen dumps, MATLAB codes, MATLAB command window print-outs, etc.) as needed in your report. Append your MATLAB code at the end of your assignment, do not upload it separately. The axes of all plots should be scaled and labeled. Typing your report instead of handwriting some parts will be better. Please do not upload any photos/images of your report. Your complete report should be uploaded on Moodle as a single good-quality pdf file by the given deadline. Please DO NOT submit any files by e-mail.

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